Library Copy
9A2Q278R02
UNCLASSIFIED

c. 2
Copy 44
RM SL54D12

3 1176 00148 7520

NACA

Classification changed to Unclassified
Authority of NASA Class Change Notices No. 19 dtd May 26, 1965
7-1-65

RESEARCH MEMORANDUM

for the

Bureau of Aeronautics, Department of the Navy

ROCKET-POWERED-MODEL INVESTIGATION OF THE EFFECTS OF AEROELASTICITY ON THE ROLLING EFFECTIVENESS OF AN 8.06-PERCENT-SCALE MCDONNELL F3H-1 AIRPLANE WING AT MACH NUMBERS FROM 0.5 TO 1.4

TED NO. NACA DE ~~207~~ 351

By Roland D. English

Langley Aeronautical Laboratory
Langley Field, Va.

CLASSIFIED DOCUMENT

This material contains information affecting the National Defense of the United States within the meaning of the espionage laws, Title 18, U.S.C., Secs. 793 and 794, the transmission or revelation of which in any manner to an unauthorized person is prohibited by law.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WASHINGTON

APR 12 1954

LIBRARY COPY

 [redacted]

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUM

for the

Bureau of Aeronautics, Department of the Navy

ROCKET-POWERED-MODEL INVESTIGATION OF THE EFFECTS OF AEROELASTICITY ON THE ROLLING EFFECTIVENESS OF AN 8.06-PERCENT-SCALE MCDONNELL F3H-1 AIRPLANE WING AT MACH NUMBERS FROM 0.5 TO 1.4

TED NO. NACA DE ~~207~~ 351

By Roland D. English

SUMMARY

At the request of the Navy Department Bureau of Aeronautics, the Langley Pilotless Aircraft Research Division has made an investigation to determine the effects of aeroelasticity on the rolling effectiveness of an 8.06-percent-scale model of the McDonnell F3H-1 airplane wing. The investigation was made by means of rocket-propelled models in free flight over a Mach number range from 0.5 to 1.4. The results of the investigation indicate that the F3H-1 airplane is subject to aeroelastic losses varying from about 7 percent at a Mach number of 0.5 to 46 percent at a Mach number of 0.90 at sea level and from about 12 percent at a Mach number of 0.5 to about 20 percent at a Mach number of 0.93 at 35,000 feet.

INTRODUCTION

At the request of the Navy Department Bureau of Aeronautics, the Langley Pilotless Aircraft Research Division has made an investigation of the rolling effectiveness of an 8.06-percent-scale model of the McDonnell F3H-1 airplane wing. The investigation was made by means of rocket-propelled models in free flight with aileron deflections of 10° and 20° at Mach numbers from 0.5 to 1.4. The primary purpose of the tests was to determine the effects of aeroelasticity on rolling effectiveness. Some data are included on the overall effects of tail damping and downwash on roll.

[redacted]

UNCLASSIFIED

SYMBOLS

b	wing span, ft
c	local wing chord, ft
C_l	rolling-moment coefficient $\left(\frac{\text{Rolling moment}}{qSb}\right)$
$C_{l_{\delta_\alpha}}$	rate of change of rolling-moment coefficient with aileron deflection, $\frac{\partial C_l}{\partial \delta_\alpha}$
C_{l_p}	rate of change of rolling-moment coefficient with wing-tip helix angle, $\frac{\partial C_l}{\partial (pb/2V)}$
M	Mach number
m	twisting couple applied at 0.94b/2 in a plane parallel to model center line, in-lb
P	load applied at 0.94b/2 on 56.8-percent-chord line, lb
p	rolling velocity, radians/sec
p_o	sea-level static pressure, lb/sq ft
p_a	static pressure at altitude, lb/sq ft
R	Reynolds number based on mean exposed wing chord (0.961 ft)
S	total wing area, sq ft
V	model flight-path velocity, ft/sec
δ	deflection of 56.8-percent-chord line, in.
δ_a	deflection of each aileron (measured perpendicular to aileron hinge line), deg
δ_{a_T}	total deflection of two ailerons (measured perpendicular to aileron hinge line), deg

[redacted]

θ angle of twist in planes parallel to model center line, radians

φ fraction of rigid-wing rolling effectiveness retained by flexible wing, $(pb/2V)_f/(pb/2V)_r$

$pb/2V$ wing-tip helix angle, radians

θ/m torsional-stiffness parameter, radians/in-lb

δ/P bending-stiffness parameter, in/lb

Subscripts:

f flexible

r rigid

DESCRIPTION OF MODELS AND TESTS

The four models tested in this investigation were 8.06-percent-scale models of the McDonnell F3H-1 airplane wing mounted on pointed cylindrical bodies (see ref. 1 for coordinates) which were equipped with four equally spaced tail fins in order to keep the models at essentially zero angle of attack and zero angle of sideslip. The wings had an aspect ratio of 2.83, a taper ratio of 0.52, a semispan of 1.42 feet, and the quarter-chord line swept back 45°. The free-stream airfoil sections were the NACA 0008.6-1.16 38/1.14 (modified) at the root and the NACA 0006.4-1.16 38/1.14 (modified) at the tip. Rolling power was provided by a 0.23c plain sealed midspan aileron. Aileron deflection δ_a was 10° for models 1, 2, and 3, and 20° for model 4. The tails of models 1, 2, and 4 were free to roll relative to the body in order to prevent any influence of the tails on rolling effectiveness. In order to obtain an indication of the change in rolling effectiveness due to the effects of tail damping and downwash, the tail fins on model 3 were fixed to the body. The geometric details and dimensions of the models are given by the photographs of figure 1 and the sketches of figure 2. The method of mounting the flexible-model wing is shown in figure 3.

The construction details of the model wings are shown in reference 2. A very stiff construction was used for models 1 and 4. The wing construction of models 2 and 3 was intended to approximate the scaled-down stiffness characteristics of the McDonnell F3H-1 wing. The torsional-stiffness characteristics of the model wings were determined by applying a twisting couple near the wing tip and measuring the resulting angle of twist at various spanwise stations. These torsional-stiffness characteristics are compared in figure 4 with the scaled-down stiffness characteristics of the full-scale airplane wing. Although the values of θ/m for the models and airplane agree over most of the span, the model wings had an appreciable value of θ/m at the wing-body juncture, whereas θ/m for the airplane was zero at this point. This discrepancy appears because the wing was attached to the body along only about 50 percent of the chord and there was no restriction to movement of the trailing half of the wing. (See fig. 3.) The spanwise variation of the bending-stiffness parameter δ/P was obtained by applying a load near the wing tip and measuring the resulting deflection of the 56.8-percent-chord line (approximate location of full-scale-airplane main spar) at various spanwise stations. The bending-stiffness characteristics of the test models are presented together with the scaled-down characteristics of the F3H-1 wing in figure 5. The scaled-down torsional- and bending-stiffness characteristics of the full-scale airplane in figures 4 and 5 were obtained from reference 2.

The models were propelled to a Mach number of approximately 1.4 by a two-stage rocket-propulsion system. During a period of free flight following burnout of the second propulsion stage, the rolling velocity, flight-path velocity, range, and altitude were recorded continuously by means of spinsonde and radar equipment. These data were used with atmospheric data obtained from radiosondes to determine the variation of the rolling-effectiveness parameter $pb/2V$ with Mach number. The range of test Reynolds numbers is presented as a function of Mach number in figure 6. A more detailed description of the test technique is given in references 2 and 3.

From previous experience, it is estimated that the accuracies of the test data are within the following limits:

	Subsonic	Supersonic
$pb/2V$	± 0.004	± 0.002
M	± 0.01	± 0.01

RESULTS AND DISCUSSION

The variation of the rolling-effectiveness parameter $pb/2V$ and the static-pressure ratio p_a/p_o with Mach number is presented for all models in figure 7. Rolling effectiveness has been corrected by the method of reference 4 for the small wing-incidence errors resulting from construction tolerances. No correction was made for the effects of moment of inertia in roll because reference 1 shows this correction to be small. The data for the stiff wing with 20° aileron deflection are to show the variation of $pb/2V$ with δ_a and are not used in the determination of aeroelastic losses.

The stiff-wing data from figure 7 for 10° aileron deflection were corrected to rigid-wing values and the rigid-wing values were used in the calculation of flexible-wing rolling effectiveness at sea level and 35,000 feet altitude by the method of reference 5. It should be noted that the scaled-down stiffness characteristics of the full-scale airplane were used in these calculations. Because the inherent error in the method of reference 5 exceeds experimental error when the loss in rolling effectiveness is greater than 50 percent, the calculations at sea level were not extended beyond $M = 0.90$. This calculated rolling effectiveness is compared with experimental rolling effectiveness and estimated rolling effectiveness from reference 2 (sea level only) in figure 8. The estimates of rolling effectiveness in reference 2 were made by using values of $C_{l_{\delta_a}}$ and C_{l_p} obtained from a correlation of theory with wind-tunnel experimental data. The experimental rolling effectiveness was corrected from model flight altitudes to sea level and 35,000 feet by assuming that loss in rolling effectiveness, $1 - \varphi$ is proportional to the static-pressure ratio p_a/p_o. Rigid-wing rolling effectiveness as calculated by the method of reference 5 and obtained from reference 2 is included in figure 8 for the purpose of comparison. The experimental losses in rolling effectiveness vary from about 47 percent at a Mach number of 0.5 to 100 percent (aileron reversal) at a Mach number of 0.93 at sea level and from about 12 percent at $M = 0.5$ to about 20 percent at $M = 0.93$ at 35,000 feet. However, these experimental aeroelastic losses at sea level are not believed to be a good estimate of the losses of the full-scale airplane. The discrepancy between model and scaled-down airplane structural characteristics has already been pointed out in the description of the model. The structural ineffectiveness of the rearward portion of the wing would allow a deflection of this portion resulting in an effective wing camber which would tend to counteract the aileron. For this reason, the experimental aeroelastic losses at sea level are believed to be high and the calculated losses of 7 percent at $M = 0.5$ and 46 percent at $M = 0.90$ are believed to be better estimates of the losses that would be experienced by the full-scale airplane. At 35,000 feet, where the aerodynamic loads are only about 23 percent of those at sea level, the effects of camber would be smaller and the experimental rolling-effectiveness losses are believed to be a good estimate of those of the full-scale airplane at subsonic speeds.

A comparison of the rolling effectiveness of the flexible wing with free-to-roll tail and with fixed tail (fig. 7) shows $pb/2V$ to be higher for the fixed-tail model over the entire Mach number range and indicates that downwash tends to increase the rolling effectiveness of the model. The difference in pb/2V values is within experimental accuracy at Mach numbers below 1.0 but at supersonic speeds is appreciable.

CONCLUDING REMARKS

Experimental results of an investigation of the effects of aeroelasticity on the rolling effectiveness of an 8.06-percent-scale model of the McDonnell F3H-1 airplane wing indicate aeroelastic losses varying from about 47 percent at a Mach number of 0.5 to 100 percent (aileron reversal) at a Mach number of 0.93 at sea level and from about 12 percent at a Mach number of 0.5 to about 20 percent at a Mach number of 0.93 at 35,000 feet. These losses at sea level, however, are believed to be high because of a discrepancy in the model and full-scale airplane structural characteristics and calculated losses of 7 percent at a Mach number of 0.5 and 46 percent at a Mach number of 0.90 are believed to be better estimates of the losses of the full-scale airplane. At 35,000 feet, the experimental losses of 12 percent at a Mach number of 0.5 to 20 percent at a Mach number of 0.93 are believed to be good estimates of the losses of the full-scale airplane.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., March 22, 1954.

Roland D. English

Roland D. English
Aeronautical Research Scientist

Approved: Joseph A. Shortal

Joseph A. Shortal
Chief of Pilotless Aircraft Research Division

MML

REFERENCES

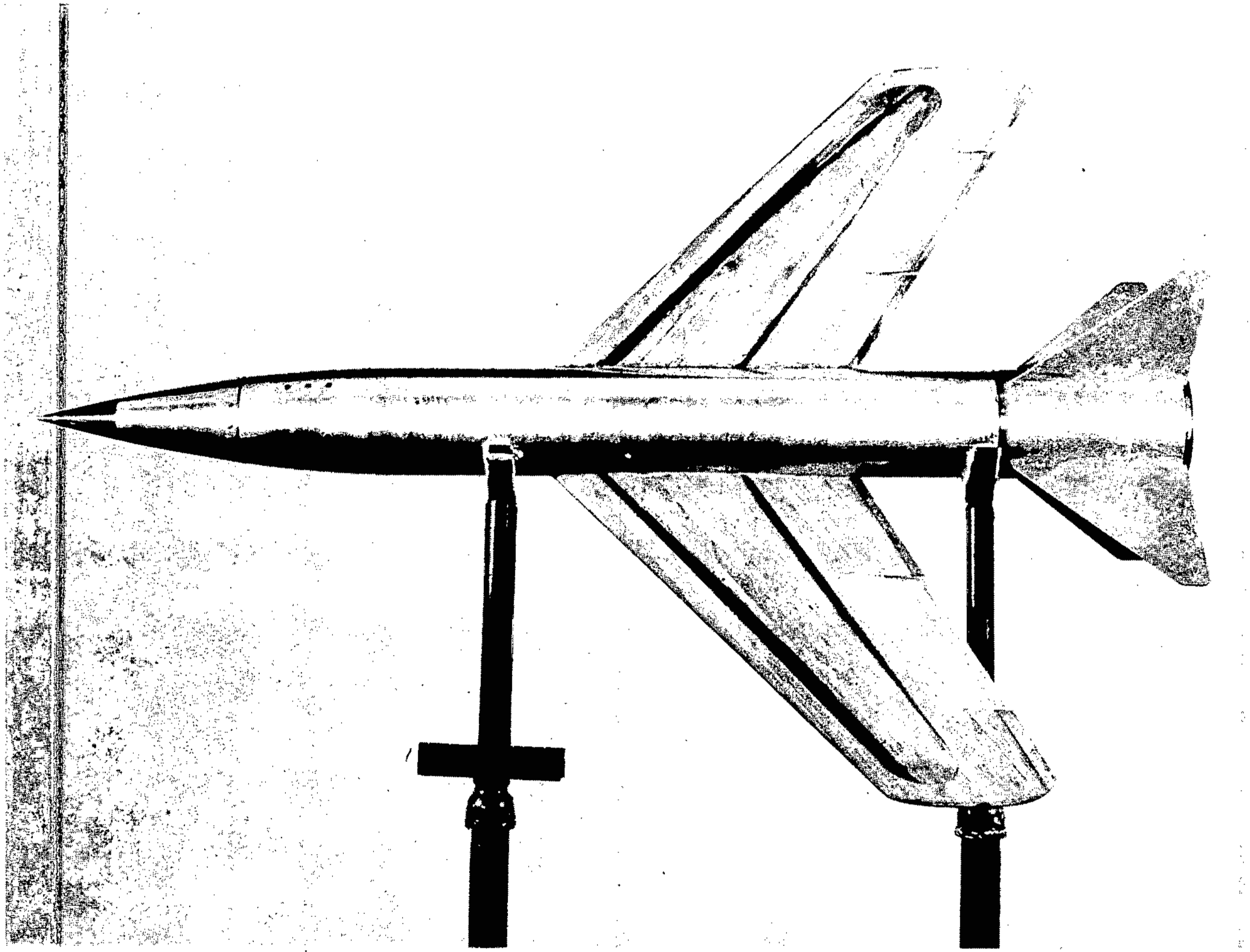
1. Sandahl, Carl A., and Marino, Alfred A.: Free-Flight Investigation of Control Effectiveness of Full-Span 0.2-Chord Plain Ailerons at High Subsonic, Transonic, and Supersonic Speeds to Determine Some Effects of Section Thickness and Wing Sweepback. NACA RM L7D02, 1947.

2. Landgraf, S. K.: Model F3H-1. F3H-1 Lateral Control Rocket Model Characteristics. Rep. No. 2646, McDonnell Aircraft Corp., July 30, 1952.

3. Pitkin, Marvin, Gardner, William N., and Curfman, Howard J., Jr.: Results of Preliminary Flight Investigation of Aerodynamic Characteristics of the NACA Two-Stage Supersonic Research Model RM-1 Stabilized in Roll at Transonic and Supersonic Velocities. NACA RM L6J23, 1947.

4. Strass, H. Kurt, and Marley, Edward T.: Rolling Effectiveness of All-Movable Wings at Small Angles of Incidence at Mach Numbers From 0.6 to 1.6. NACA RM L51H03, 1951.

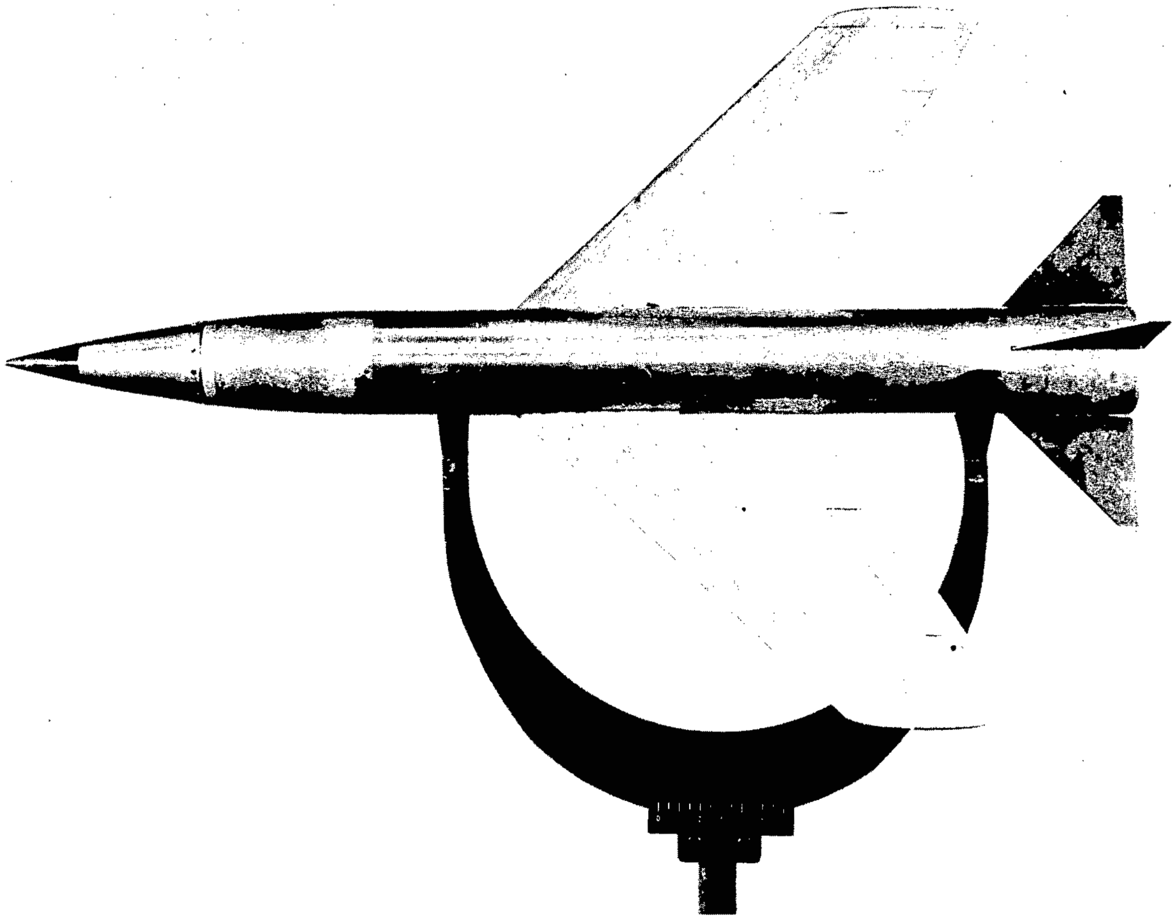
5. Strass, H. Kurt, and Stephens, Emily W.: An Engineering Method for the Determination of Aeroelastic Effects Upon the Rolling Effectiveness of Ailerons on Swept Wings. NACA RM L53H14, 1953.



L-78038.1

(a) Model 1.

Figure 1.- Photographs of typical test models.

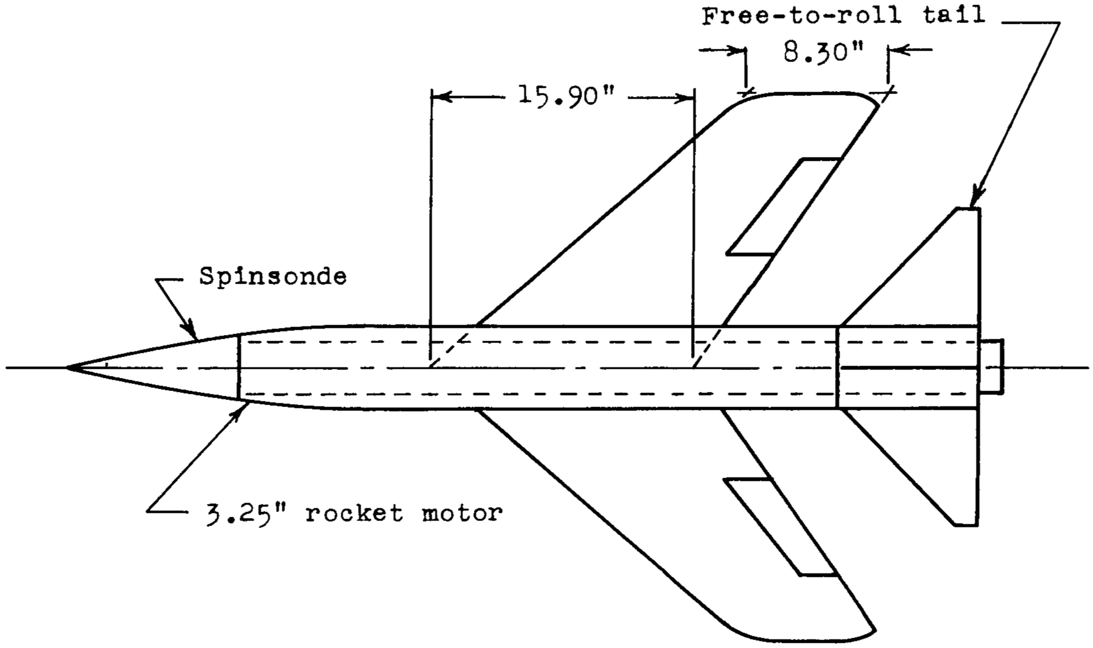


L-78187.1

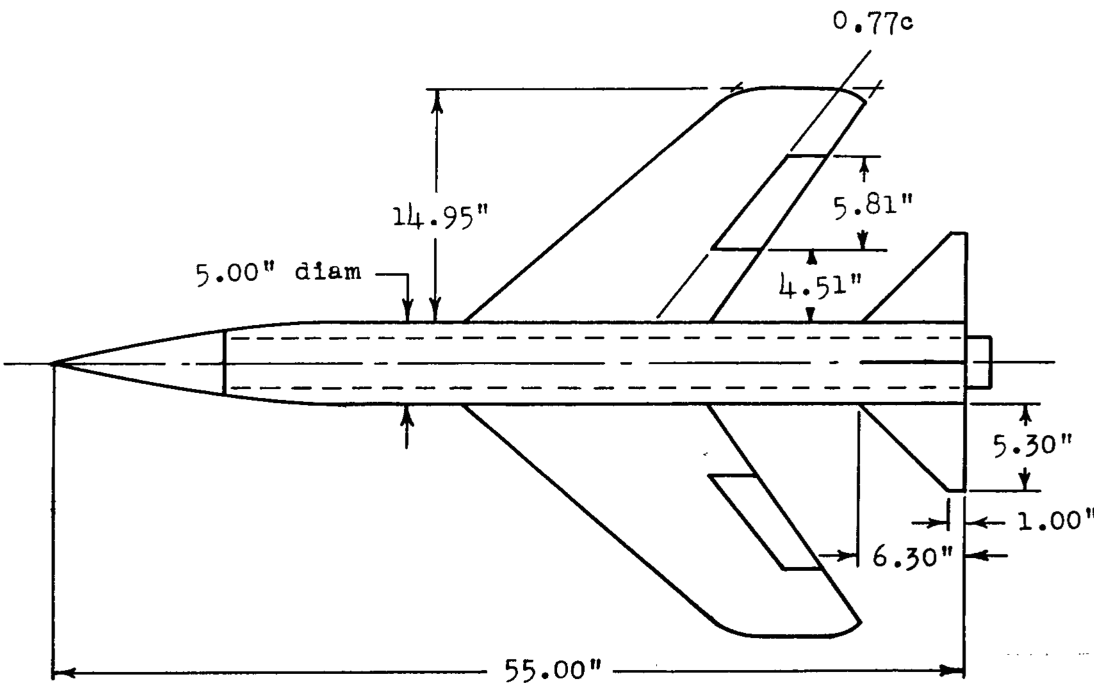
(b) Model 3.

Figure 1.- Concluded.

 [redacted]



Models 1(stiff, δ_a=10°), 2(flexible, δ_a=10°), and 4(stiff, δ_a=20°)



Model 3(flexible, δ_a=10°)

Figure 2.- Sketches of test models.

[redacted]

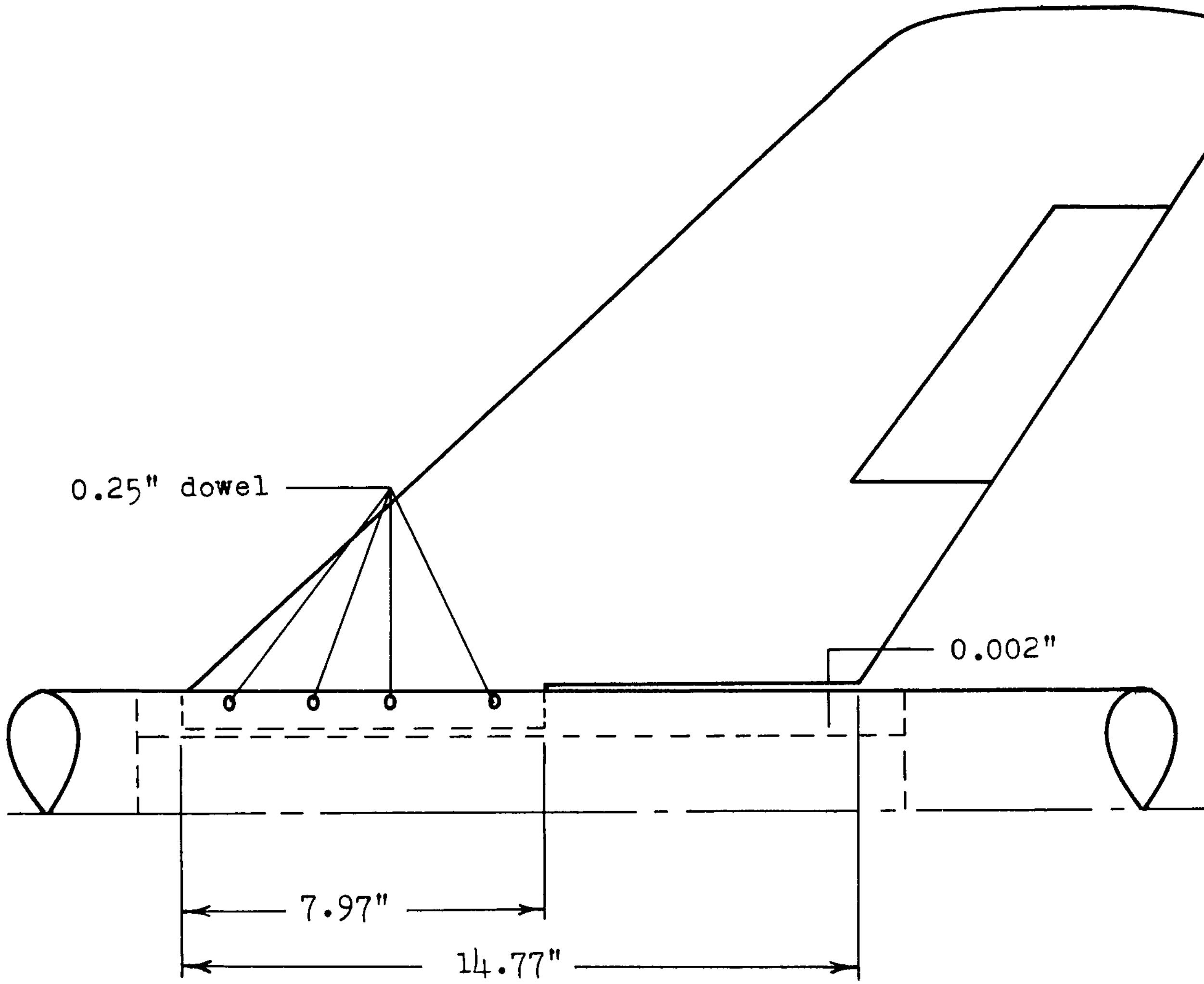


Figure 3.- Sketch showing method of mounting the flexible-model wing.

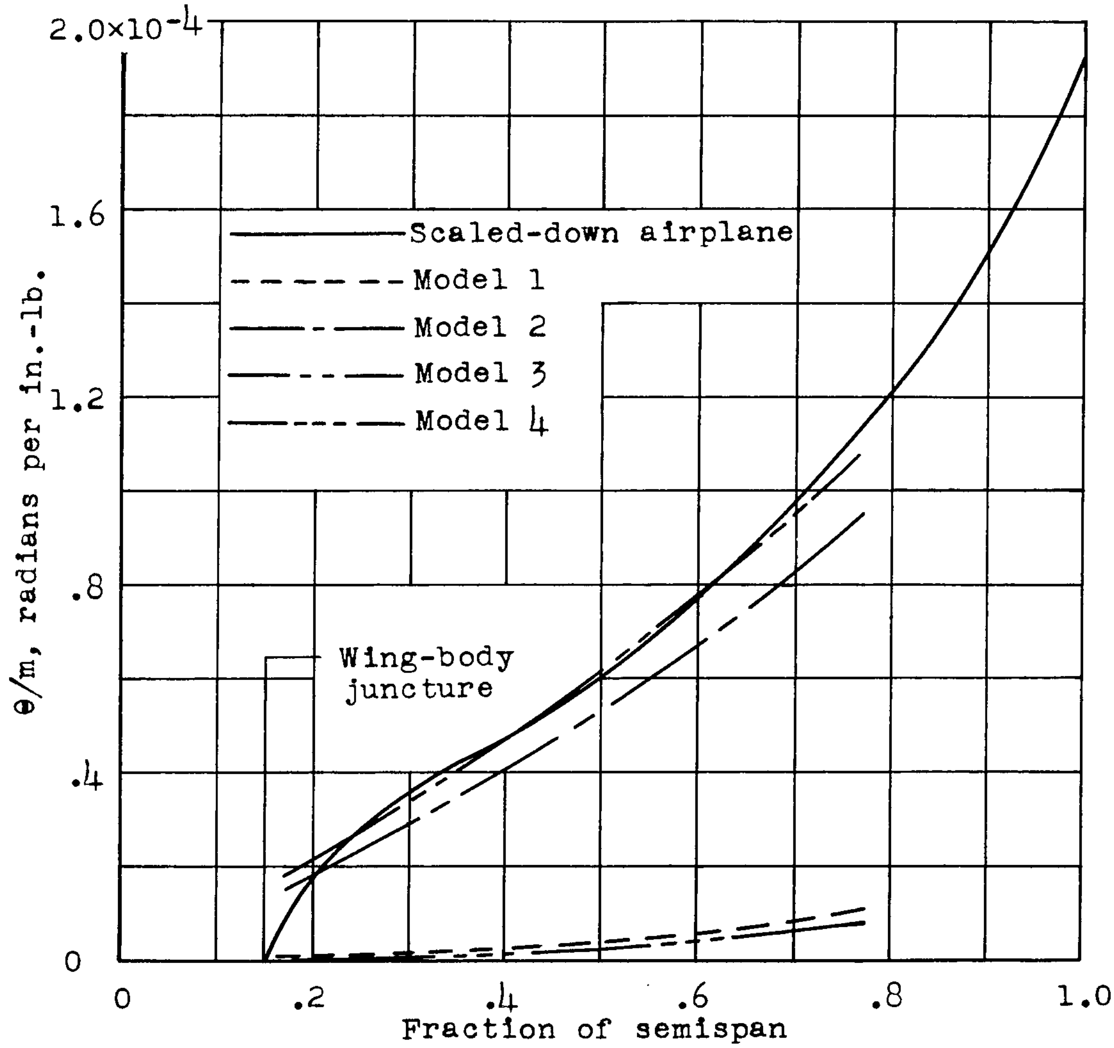


Figure 4.- Spanwise variation of torsional-stiffness parameter θ/m.

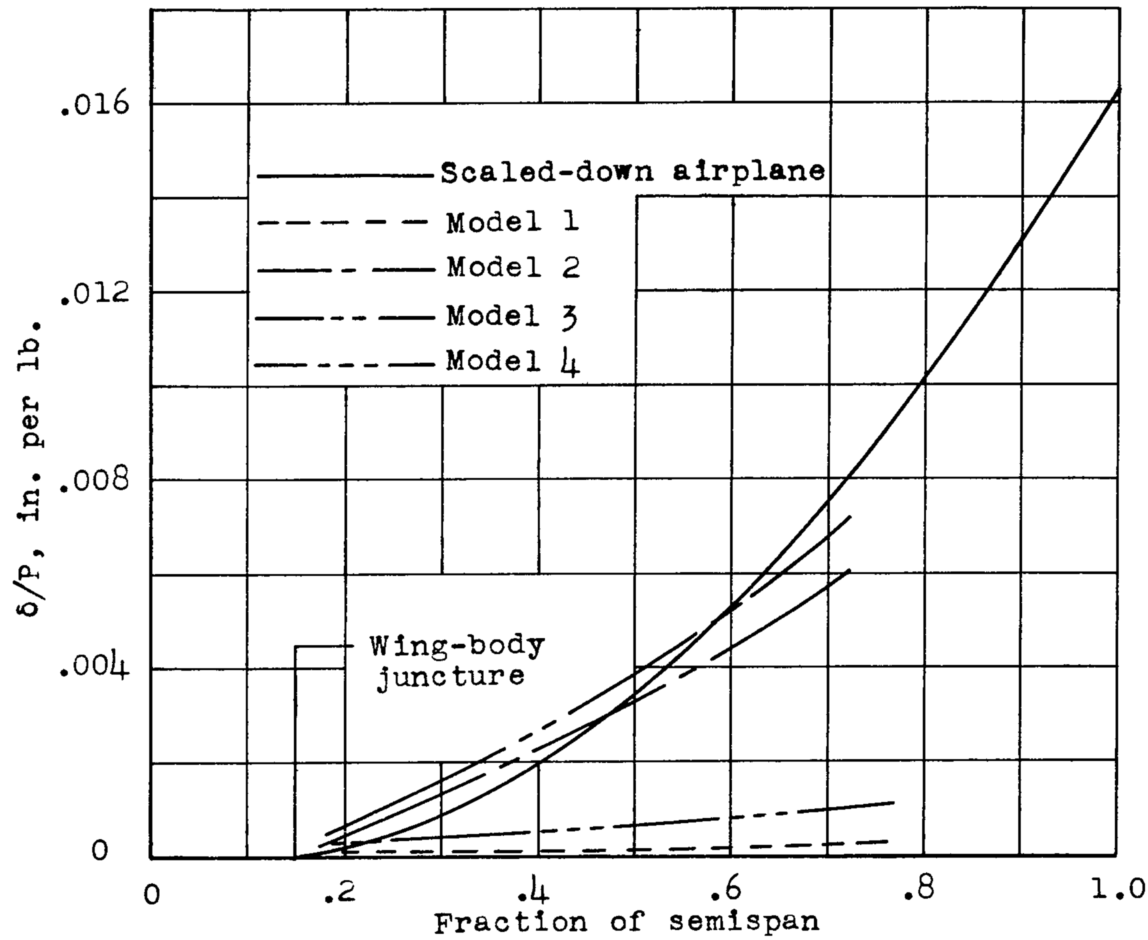


Figure 5.- Spanwise variation of bending-stiffness parameter δ/P.

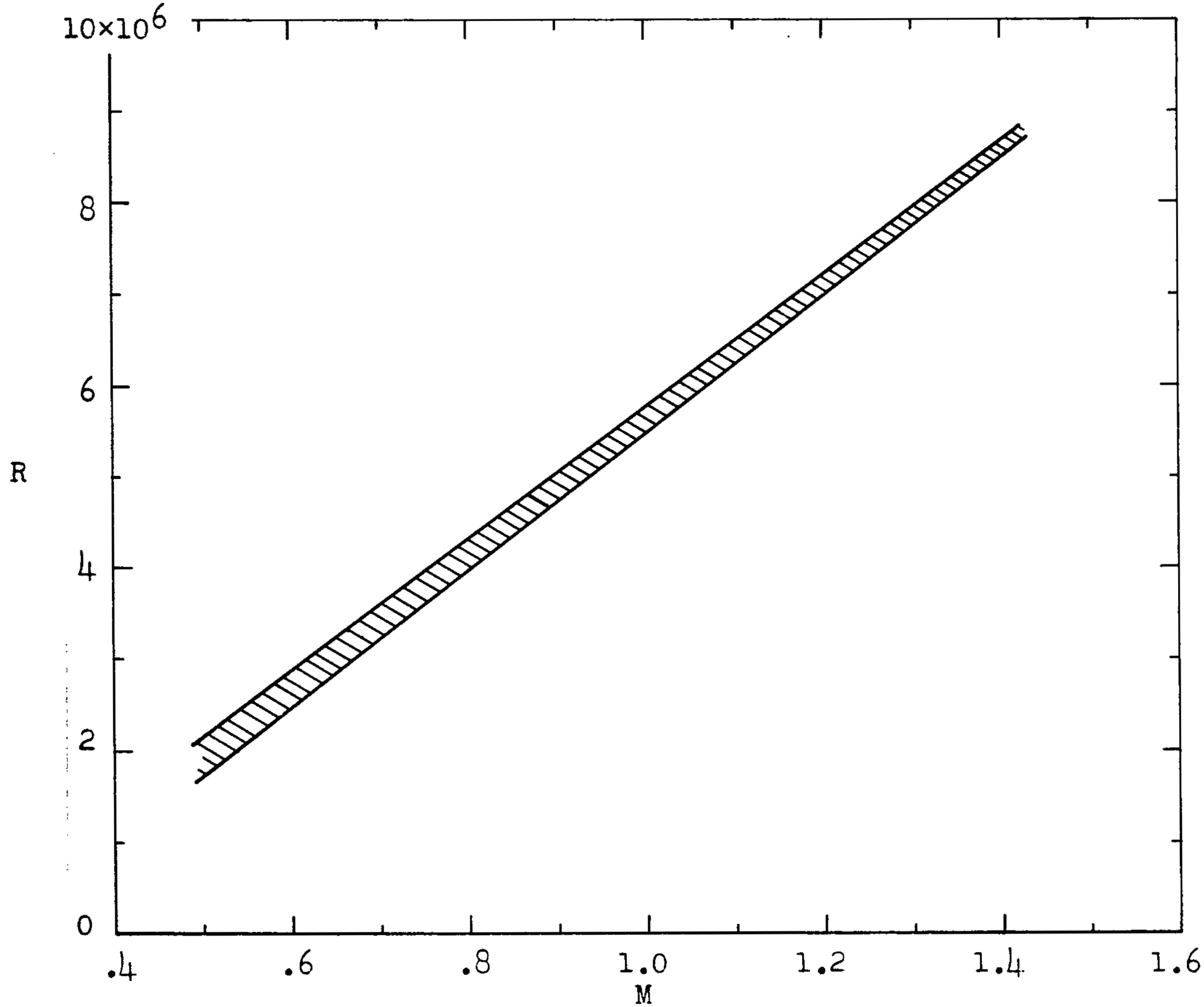
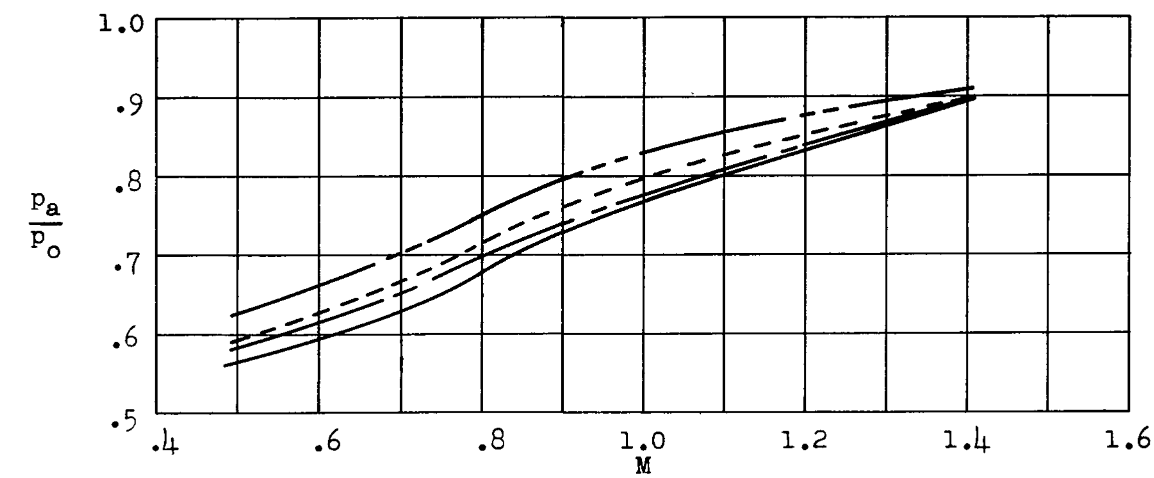


Figure 6.- Variation of test Reynolds numbers with Mach number. Reynolds numbers based on mean exposed wing chord, 0.961 foot.

[redacted]



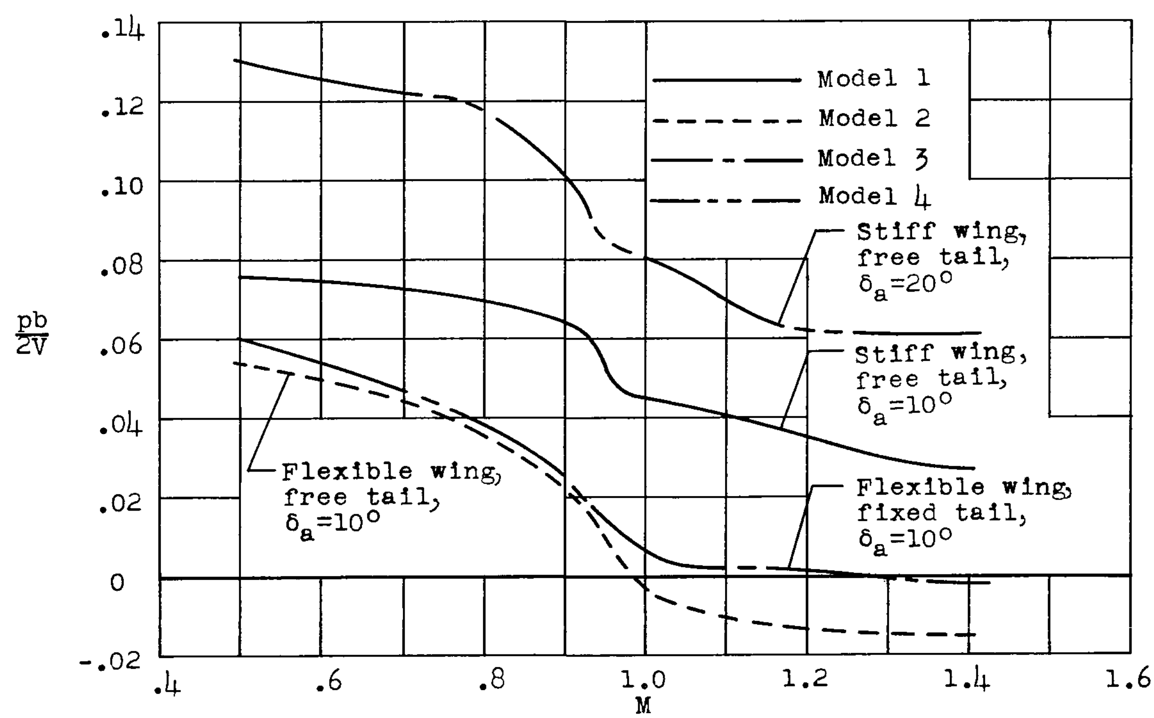
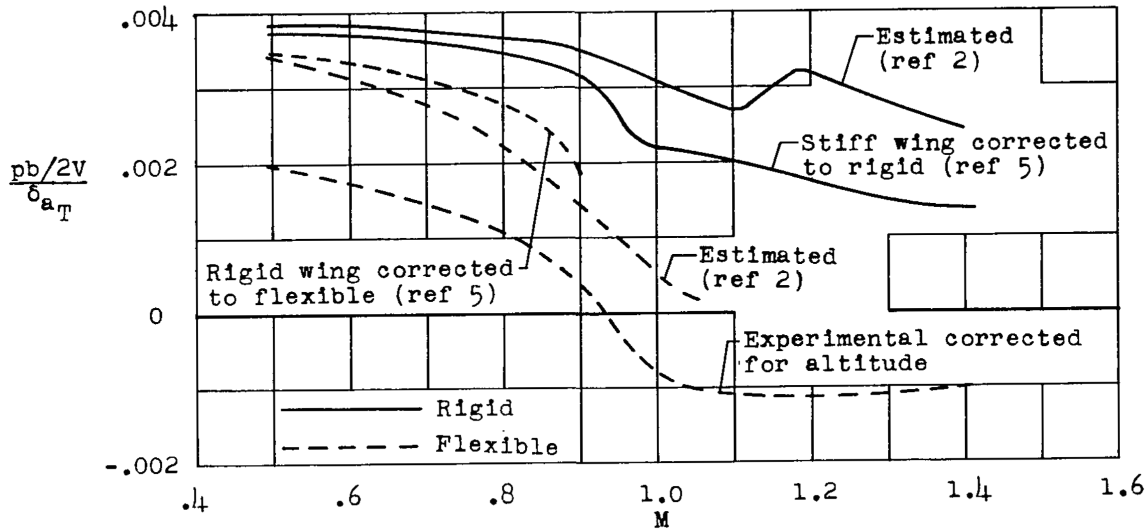
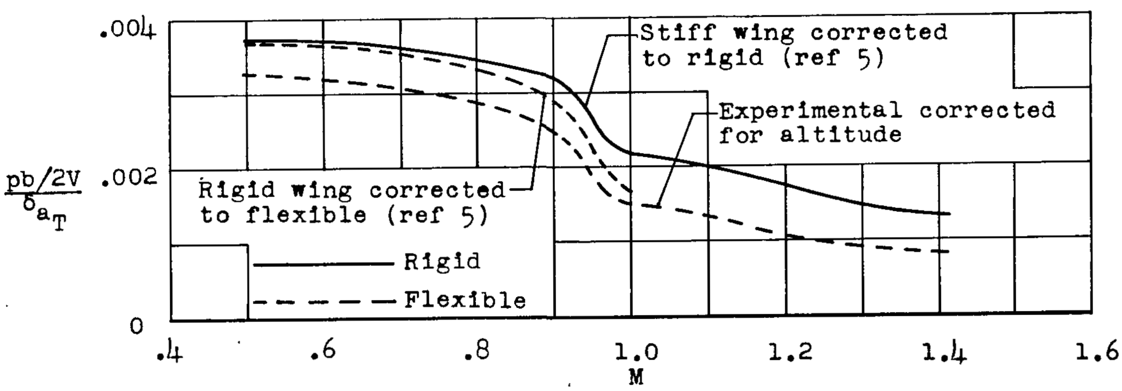


Figure 7.- Variation of rolling-effectiveness parameter $pb/2V$ and static-pressure ratio p_a/p_o with Mach number.

[redacted]



(a) Sea level.



(b) 35,000 feet.

Figure 8.- Comparison of calculated and experimental rolling effectiveness.